SEA-STARS OF THE OGASAWARA ISLANDS

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ONE PLATE AND FIVE TEXT-FIGURES

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The material described in this paper consists of the sea-stars deposited among the late Prof. S. Goto's large collection, which were obtained by Messrs. Hirota and Sekiguchi from the Ogasawara Islands in 1894. Sea-stars of the Islands have not been reported by any investigator, so the writer here reports the following species, though none new to science, 3 species of them being new to Japan.

Species	Localities
Fromia indica Perrier	Chichijima & Anijima
Nardoa frianti Koehler	Between Chichijima & Anijima
Ophidiaster cribrarius Lütken	Chichijima
Linckia multifora (Lamark)	Chichijima & Anijima
Echinaster luzonicus (Gray)	Chichijima & Anijima
Coscinasterias acutispina Stimpson	Chichijima & Anijima

Before going further the writer must express his hearty thanks to Prof. Tohru Uchida for his kind guidance and for placing Prof. Goto's specimens at the writer's disposal.

Fromia indica Perrier

(Pl. 4, figs. 1–4)

Fromia indica: Perrier, 1875, p. 441; Koehler, 1910, p. 140, pl. 17, figs. 7, 8.

Thirteen specimens in Goto's collection were examined. This species has not been recorded from Japan. The writer remarks in another paper[1], "*Fromia indica* seems to be very diverse in its external features, and the 2 sea-stars, *F. andamanensis* and *F. elegans*, are referable to the forma of the species". As described in this paper the

[1] Sea-stars of the Caroline Islands" which will be published as one of the Palao Tropical Biological Station Studies.

species is extremely variable. Though Clark ('21) mentions, "It should be remembered that the holotype of *indica* is hexamerous", our examples are always pentamerous as in Bell's record ('82). The measurements are as follows:

R	r
20 mm	6.5 mm
28 mm	8 mm
31 mm	9 mm
31 mm	9 mm
31 mm	9 mm
32 mm	9.5 mm
32 mm	9 mm
32 mm	8.5 mm
32 mm	8.5 mm
33 mm	9 mm
34 mm	9.5 mm
35 mm	9.5 mm
35 mm	10 mm

The ratio between R and r ranges from R=3r to R=4r.

Body relatively compressed or moderately swollen. Rays more or less swollen in the abactinal side and flattened in the actinal side; in the *andamanensis*-forms the rays have a tendency to become subcircular in the cross section. Abactinal plates very diverse in size and form, generally wider than long at least at the arm base. In the *andamanensis*-forms these plates are small, numerous, flat, not convex or swollen, the primary interradial plates being hardly distinguished from the others, only slightly different in a little larger size. In the *elegans*-forms the abactinals are rather small and flat, but a number of them are conspicuously large and convex or swollen, and also the primary interradials are swollen, roundish in form, easily recognized; in the *indica*-forms there are much more convex abactinals than are those in *elegans*-forms; the abactinals are arranged more or less in 2 or 3 longiseries. Although there can be observed great diversities in individuals with regard to the size and form of the abactinals, these variations are not seemingly due to differences in growth stages. A small example (R 20 mm) has a number of large swollen abactinals, while a larger specimen (R 35 mm) carries only small, flat, not swollen nor convex, ones. The plates are each uniformly covered with rounded coarse granules forming a distinct group on each plate. Terminal plates small, roundish in form. The granulation of the distal plates including a terminal one is a little coarser than that of other abactinals. Abactinal papulae numerous, isolated, scattered all over the abactinal surface.

Marginal plates widely variable in features in this species, arranged regularly on the lateral margin of the body. Superomarginals, 19–21 in number, a little wider than long or squarish in form. Inferomarginals generally agreeing with the superomarginals in number, form and position, the former however being often longer than wide or smaller than the latter. In some examples inferomarginals do not

correspond perfectly in position to the superomarginals; the latter being fewer (2-3) than the former. Exceptionally in one example (R 35 mm) the marginals are inconspicuous, arranged irregularly at least in the distal half of the ray, and are scarcely distinguished from the abactinals. The granulation of marginal plates is quite similar to that of the abactinals, and the granules covering the inferomarginals are sometimes a little coarser than those on the superomarginals, especially on the inner end of the plates and on several distal plates.

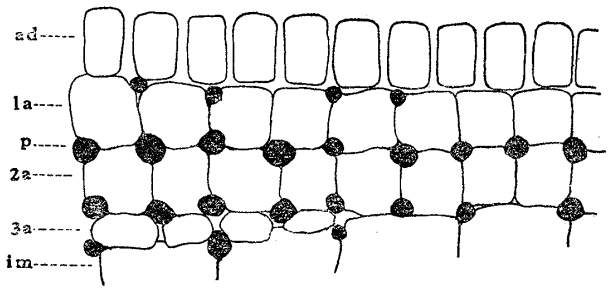


Fig. 1. *Fromia indica.* Schematic diagram showing the arrangement of actinal papulae in proximal portion of ray, ×20; ad adambulacral series, 1a 1st actinal series, 2a 2nd actinal series, 3a 3rd actinal series, im inferomarginal series, p actinal papulae.

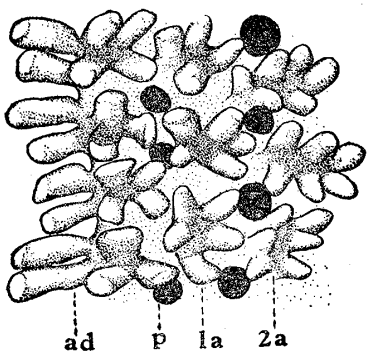


Fig. 2. *Fromia indica.* Actinal spines, ×25; ad adambulacral spines, 1a 1st actinal spines, 2a 2nd actinal spines, p papulae.

Actinal plates, 2 to each inferomarginal plate, squarish or roundish in form, arranged in 3 or 4 longiseries. In a large example (R 32 mm) the 1st actinal series adjoining the adambulacrals is most developed, reaching the arm tip. The 2nd actinal series extends more than 3/4 the length of ray, the 3rd one nearly half length of the ray, and the 4th one is rudimentary, represented by a few small plates. In a small example (R 20 mm) the actinals are arranged in 3 series, of which the 3rd is rudimentary. Each plate is crowded with a group of 4–12 coarser granules with a round tip. The groups are more or less interspaced. Actinal papulae isolated, arranged in regular longiseries, each papula located on the corners of the actinal plates. In large specimens there are observed 4 series of the organs in the proximal portion of ray. The 2 median series are well developed, reaching nearly the arm tip, and the outermost series placed between the 3rd actinal and inferomarginal plates is rudimentary. It must be noted that the innermost series between the 1st actinal and adambulacral plates is rudimentary or fairly developed in some specimens.

Adambulacral plates, 2 or 3 to each inferomarginal plate, wider than long. The armature is composed of 3 longiseries of spines. The furrow series consists of subequal, compressed, thick spines with a rounded tip, mostly 2 in number, frequently 1 or 3 in each plate. The series of subambulacral spines is represented by thick, blunt spines, shorter than furrow spines, generally 2 in number, occasionally 1 or 3 in each plate. The outer series is mostly composed of 2, frequently 1 or 3 much smaller, bluntly pointed spines in each plate. Oral plates have each 4 furrow spines.

Madreporite small, circular, situated about midway between the centre and the margin of the disc.

Remarks. Judging from Clark's descriptions of *F. elegans* ('21, '24), Koehler's ('09) and Clark's ('23) descriptions of *F. andamanensis* and Perrier's ('75) description and Koehler's ('10) figures of *F. indica*, the above 3 *Fromia*s are very closely related. The differences of the form and arrangement of abactinal plates and the ratio of R and r have been mainly used to distinguish them. Having examined the present specimens from the same locality, however, the writer has come to the conclusion that the abactinals and marginals in this species are subject to a very diverse individual variation, and thence the 3 *Fromia*s cannot be distinguished in these features. So the writer is of the opinion that the 2 *Fromia*s, *elegans* and *andamanensis*, are to be referred merely to forma of *F. indica*.

Nardoa frianti Koehler

(Pl. 4, figs. 5, 6)

Nardoa frianti: Koehler, 1910, pp. 158–161, pl. 17, figs. 3, 4.

The writer examined 2 specimens of *Nardoa*, the one measuring 60 mm in R, 11 mm in r and the other 64 mm in R, 10 mm in r. These specimens are in general agreement with *Nardoa frianti*, though with fewer tubercles on the abactinal surface. This species has not previously been recorded in Japan.

The description of one example (R 60 mm) is as follows: Disc elevated, rays gradually tapering to the tip, 5 in number. Abactinal plates arranged irregularly and very diverse in size and form. On the disc and proximal half portion of ray there are prominent cylindrical or spherical tubercles which measure 3 mm–4 mm wide and 2.5 mm–3 mm high, but the plates situated in the distal half portion of ray are smaller, relatively uniform in size and mostly longer than wide. Abactinal surface covered with compact polygonal granules, of those on the tubero-

sities are larger than those on papular areas. There are small scattered abactinal papular areas on the disc and rays, each containing 5–6 (1–7) pores, but absent in the distal portion of the ray. Terminal plates subcircular or subtriangular in form, invested with granules identical with those on abactinals.

Marginal plates conspicuous, arranged in regular longiseries. Superomarginals swollen, 30–34 in number, with a tendency for roundish swollen plates and smaller ones, wider than long, to be arranged in alternative position. The several proximal plates are much tuberculated in a dome-shape. Inferomarginals swollen, slightly fewer than superomarginals, 27–31 in number. In the proximal portion of ray these plates are wider than long, gradually decreasing in size towards the arm tip, and squarish or roundish in form in the middle and distal portions of ray. There are no such tubercular plates as in the superomarginals. Between the 2 marginals there is a series of intermarginal plates extending along the middle length of ray. Intermarginal papular areas 2 in longiseries in the proximal portion of ray, each with 1–6 pores. The 2 series merge into one about the middle length of the ray and then disappear near the arm tip. In another specimen (R 64 mm) the intermarginals absent, the papular areas are arranged in a series, reaching two-thirds the length of the ray. The granulation of marginal plates is similar to that of abactinals.

Actinal plates, 1 or 2 to each inferomarginal plate, longer than wide, squarish in form, extending beyond the two-thirds point of ray. There are no papular areas between the inferomarginals and actinals. These plates are covered with granules like those of inforomarginals.

Adambulacral plates, 2 (3) in each inferomarginal plate, wider than long. The armature is composed of 2 rows of spines and granules. The innermost row is formed of thick, prismatic or square shaped furrow spines with a rounded tip. The spines are arranged in a slightly oblique row in each plate and number 4 on proximal plates, 3 in the middle portion of ray and 2 in the distal. The row of subambulacral spines consists of short, thick, squarish or subtriangular spines with a rounded tip. The spines are arranged in a slightly oblique row in each plate, 4 or 3 in number in the proximal and the middle portions of ray, 2 or 1 on distal plates. The outer margin of each plate is covered with 2 series of granules, one is formed of much shorter spines or coarse granules, 2–4 in number and the other is represented by 2–4 very coarse granules. Oral plates have each 6–7 furrow spines. No pedicellariae anywhere.

Madreporite small, roundish in form, situated about midway between the centre and the margin of disc.

Ophidiaster cribrarius Lütken

(Pl. 4, figs. 7–13)

Ophidiaster cribrarius: Lütken, 1871; Clark, 1921, p. 84.
Ophidiaster germani: Perrier, 1875, pp. 394–396.

The writer examined several small sea-stars which seem to be referable to the species. The species already known from New Caledonia and Tonga is known as a fissiparous sea-star. The species has not previously been recorded in Japan. The measurements are as follows:

Number of rays	R	r	Number of madreporites
5	18 mm–20 mm	5 mm	2
5	37 mm–45 mm	6 mm	2
5	6 mm–51 mm	6 mm	2
5	12 mm–33 mm	6 mm	2
6	12 mm–37 mm	6 mm	2
6	20 mm–31 mm	5.5 mm	2

The writer also cellected many examples of the sea-star from Tomioka (Kyushu) in 1933. They live upon or on the sides of rocks on shore, and are dark reddish brown in life.

The descriptions are as follows: Disc small, relatively flat; rays long and narrow, with obtuse tips, nearly circular in cross section. Specimens with symmetrical rays are very scarce; the rays are very diverse in number, mostly 5 or 6, but 4– or 7– rayed specimens are not rare, with exceptionally 9-rayed ones. Comet forms and abnormally branched examples are not rare.

Abactinal and marginal plates are subcordate in form, the adcentral narrowed end overlying the broader end, and each plate is transversely connected with each other by a small rod-like transverse ossicle, i.e. these plates arranged in regular longi- and transverse series as is found in *Leiaster*. The longiseries, 7 in number, form each slightly convex ridges, each separated by a series of papular areas forming a shallow groove. The areas between the transverse ossicles extend to the arm tip, each containing 6 12 pores (2–3 pores near the arm tip). The abactinal surface including marginals is closely invested with small granules, variable in size. The granules covering the convex surface

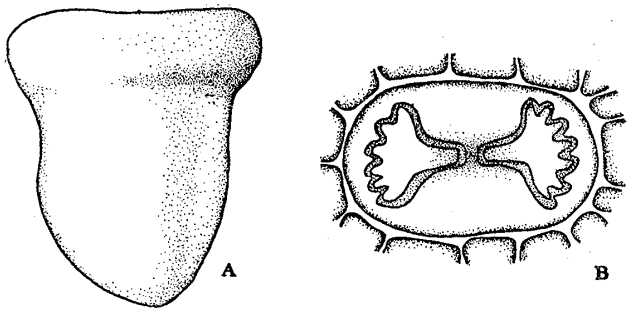


Fig. 3. *Ophidiaster cribrarius.* Abactinal pedicellaria, 80×; A, pedicellaria viewed from lateral side; B, pedicellaria viewed from abactinal side;

of plates are a little coarser than those on the papular areas, but are not prominent enough to attract the attention. There are many small alveolar excavate pedicellariae in papular areas, mostly 1 or 2 in an area.

There is a series of actinal plates, 2 to each inferomarginals plate, extending to the arm tip. These plates are different in form; the large and small ones being regularly alternative in position. The large ones are wider than long, each joined with a corresponding inferomarginal plate, and the smaller ones are roundish in form. Actinal papular areas intervening between the actinal and inferomarginal series are well developed and reach the arm tip, each containing 5–10 pores and alveolar pedicellariae. The granulation of actinal plates is similar to that of the dorsal surface.

Adambulacral plates, 2 or 3 to each inferomaginal plate, wider than long. There are no papulae and pedicellariae between the adambulacral and actinal series. The plates are each armed with 2 series of spines and granules The furrow series is composed of subequal, broad truncate spines, 2 in each plate, but occasionally 3 in the proximal portion of ray and 1 in the distal portion. Oral plates are each provided with 4–5 spines. One or 2 granules invading from the actinal surface present between the furrow spines on the inner surface of furrow. The outer margin of the plates is covered with granules identical with those of actinal plates, and there is a series of thick, ovoid or acorn-shaped subambulacral spines, 1 in each plate, but some of the plates lack the spine.

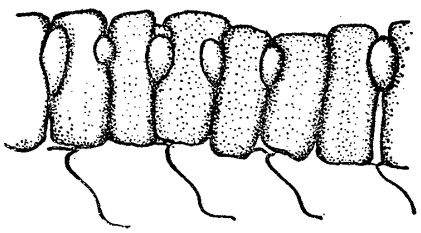


Fig. 4. *Ophidiaster cribrarius.* Adambulacral spines viewed from furrow surface, ×25.

Madreporites, 2 in number, small and subcircular in form, located on the side of ray, nearer the margin than the centre of disc.

Linckia multifora (Lamark)

Thirty-eight specimens of the species were examined. These examples are probably the materials used by S. Hirota ('95). Each example with 5 rays, with the exception of one example having 4 rays. The largest specimen measurs 43 mm–82 mm in R, 10 mm in r and the smallest one 21 mm–22 mm in R, 4 mm in r.

Echinaster luzonicus (Gray)

Fourteen specimens were examined, 2 of them with 5 rays, 10 with 6 rays and 2 assuming a comet form with 6 rays. The largest specimen measures 32 mm–50 mm in R, 9 mm in r, and the smallest one 19 mm in R, 6 mm in r. The writer has nothing to add to the description of this species in his another paper[1].

Djakonov ('30) recorded a sea-star, *Othilia purpurea* Gray, from the Riukyu Islands. Inferring from the descriptions of Djakonov, Clark ('21) and Fisher ('19, '25), Djakonov's *O. purpurea* seems to be referable to the present species.

Coscinasterias acutispina Stimpson

This fissiparous sea-star is widely distributed on the southern coasts of Japan. The writer examined 16 specimens from the Ogasawara Is. and many specimens from several localities of Japan such as Kakeroma (Amamiôshima), Tomioka, Yenoshima and Kominato.

The descriptions of Japanese specimens are as follows:

Body covered with tough skin. Disc small; rays long and narrow, 7 to 10 in number, easily fissiparous always at the arm base. Abactinal skeleton open meshed. All carinal plates having 4 lobes arranged in a straight longiseries, but occasionally more or less irregular in the proximal portion of ray, each with an acute spine, frequently compressed at the tip or bluntly pointed. In some examples the spines are located on alternative plates at least in the distal half of ray and rarely 2 spines occur in the proximal portion of ray. On both sides of the carinal row there are dorsolateral spines in a longiseries, but in

[1] loc. cit.

some examples the spines are arranged more or less in a zigzag or irregular row in the proximal portion of the ray. The series is separated from the carinal and superomarginal rows by an intermediate series of papular areas, each containing 4–7 pores. These plates have each 4 or more lobes. These dorsal spines are each provided with a collar of crossed pedicellariae, measuring about 0.3 mm–0.35 mm in length. Marginal plates arranged in regular longiseries. Superomarginals having mostly 4 lobes correspond to inferomarginals in number and position. The intermarginal areas are comparatively wide and are marked with a series of papular areas, each having 5–7 pores. The superomarginal spines, 1 for a plate, are larger than the dorsal ones and slightly compressed at the tip. The spines have each a collar of crossed pedicellariae and are located regularly on the alternative plates. Inferomarginals longer than wide, with 3 or 4 lobes, one of the lobes connected to a corresponding superomarginal plate. The plates are each armed with 2 distinctly large spines compressed at the tip, arranged in a slightly oblique row, and occasionally with 3 spines occurring in the proximal portion of ray. The outermost spines carry each a cluster of crossed pedicellariae. Actinal plates mostly absent, and when present, rudimentary, not extending for half the length of ray. Adambulacrals adjoining the inferomarginals are numerous, each provided with a furrow spine, rarely 2 in the proximal portion of ray. The spines are flattened, slender, without accessory pedicellariae. Straight pedicellariae measuring 0.6 mm–1 mm in length, scattered along the furrow margin and actinal interradial areas. Mouth plates broad, each with 2 oral spines; the mouth angle are not very constricted; 2 or 3 contiguous pairs of adambulacral plates are observed behind the plates. Madreporites roundish in form, 3 or 4 in number, located about midway between the centre and the margin of disc.

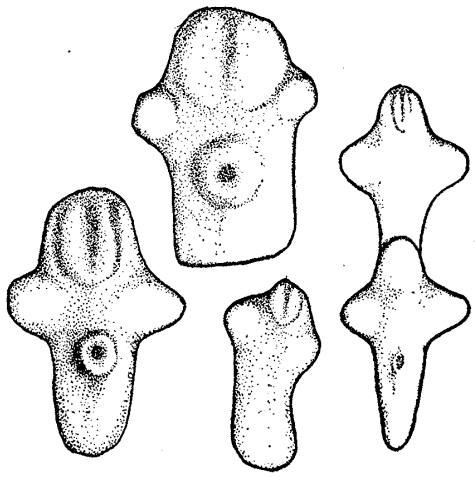


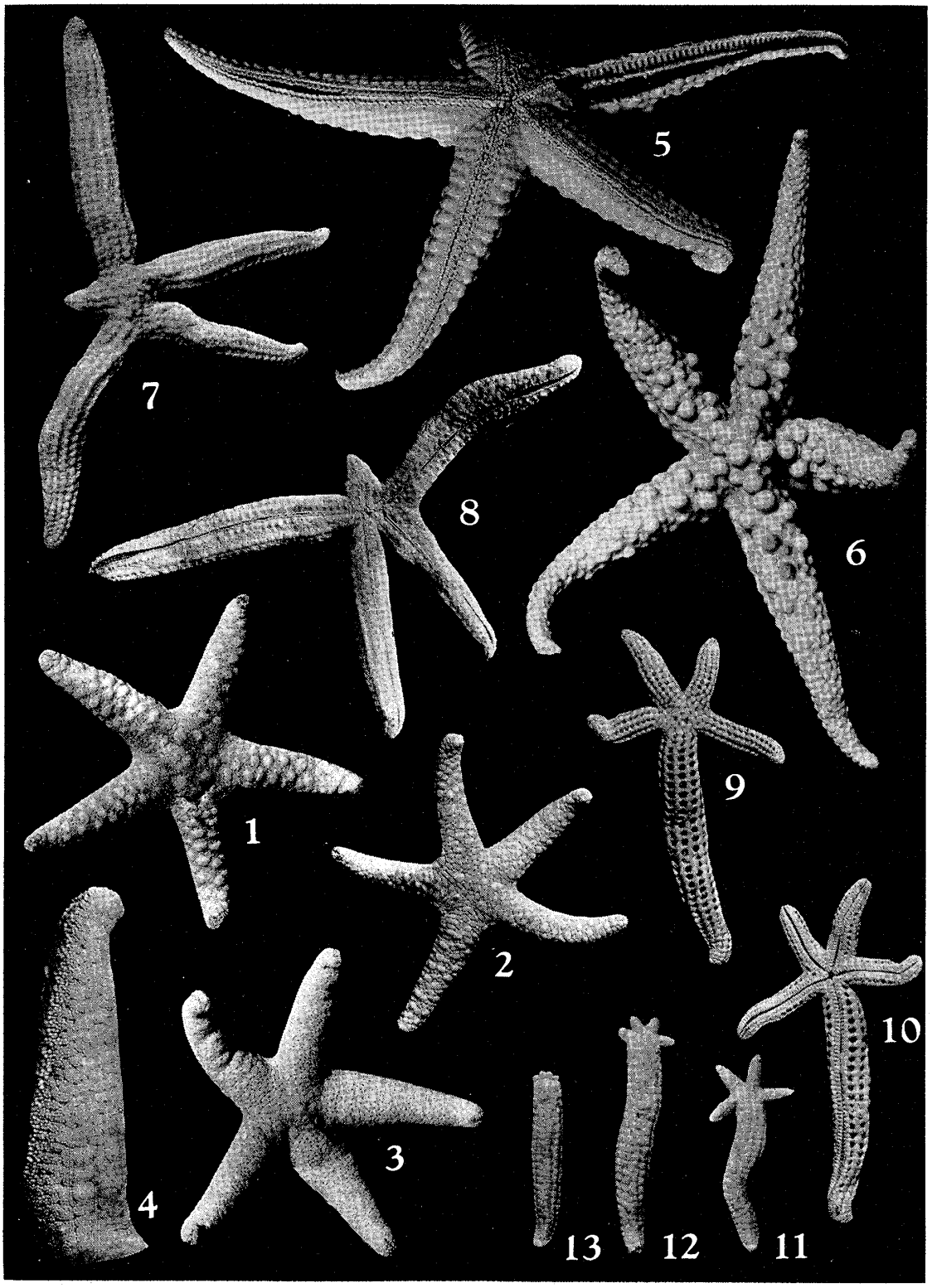
Fig. 5. *Coscinasterias acutispina.* Carinal plates viewed from abactinal surface. ×20.

Remarks. So far as the writer examined, Japanese specimens indicate chararacteristic features of the subgenus, *Stolasterias*, distributed over the northern hemisphere. Judging from descriptions, *C. acutispina*

only differs from *C. calamaria* in the alternate plates of the carinal row and the mouth angle and the latter species is ascribed to the other subgenus, *Coscinasterias*, distributed over the southern hemisphere. Regarding the 2 sea-stars, *tenuispina* and *acutispina*, belonging to the same subgenus, the writer could not find characteristic differences between them; the irregularly of the carinal and dorsolateral spines in the arrangement is seemingly worthless to distinguish them. Though the writer can not discuss decidedly here without examining the type specimen of *tenuispina*, Japanese sea-stars known as *C. acutispina* or *C. calamaria* var. *japonica* seem to be united into a single species, *C. tenuispina* (Lamark).

EXPLANATION OF PLATE

Fig. 1. *Fromia indica* (*indica* form); abactinal surface. ×3/4.
Fig. 2. *Fromia indica* (*elegans* form); abactinal surface. ×3/4.
Fig. 3. *Fromia indica* (*andamanensis* form); abactinal surface. ×3/4.
Fig. 4. *Fromia indica*; side view of a ray, showing irregular arrangement of marginal plates. ×2.
Fig. 5. *Nardoa frianti*; actinal surface. ×3/4.
Fig. 6. *Nardoa frianti*; abactinal surface. ×3/4.
Fig. 7. *Ophidiaster cribrarius*; abactinal surface. ×3/4
Fig. 8. *Ophidiaster cribrarius*; actinal surface, with a bifurcated ray. ×3/4.
Fig. 9. *Ophidiaster cribrarius*; abactinal skeleton. ×3/4.
Fig. 10. *Ophidiaster cribrarius*; actinal skeleton. ×3/4.
Fig. 11, 12, 13. *Ophidiaster cribrarius*; comet forms. ×3/4.



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